LONG WAVES

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IN this discussion, waves of a frequency below 1,500 kilocycles are defined as low frequencies or long waves, as distinguished from those above 550 kilocycles commonly called high frequencies or short waves. The frequencies from 1,500 to 550 kilocycles comprise the band of wave lengths used for broadcasting in America, and are generally known as the intermediate frequencies or waves.

When the layman read in the daily press the complete accounts sent out by Commander Byrd of the doings of his party close to the South Pole, and was told that this excellent communication direct from the Antarctic to New York would be impossible except for the short waves, he may have wondered why long waves are used at all for long-distance communication.

The relative advantages of the long and short waves form a rather complicated subject for consideration. In order to make clear the reasons for choosing different wave lengths for different purposes, it will be necessary to give some explanation of the way in which the waves travel.

It is generally accepted that the wave radiated from an ordinary antenna spreads out in a hemispherical form, extending out in every direction except into the earth. At a height of about 60 or 70 miles, this wave front reaches an ionized conducting region of the atmosphere known as

the Kennelly-Heaviside Layer. This stratum is of such a character that the waves, at least the longer ones, do not generally penetrate it to any extent, but are reflected somewhat like light from a rather poor mirror. A portion of this reflected wave reaches the receiving station, while at the same time the lower part of the wave front has been traveling along the ground to the same point. The two waves, in general, arrive in different phase on account of the difference in the length of their paths. This frequently produces fading in the region where their intensities are of the same order of magnitude. The wave which has been reflected is often spoken of as the reflected or downcoming wave, while the wave along the ground is known as the direct or ground wave. Both the ground and reflected waves are subject to absorption along their paths, and, in addition, the downcoming wave has its plane of polarization (direction of oscillation) twisted about in various ways by the earth's magnetic field. The ground wave absorption becomes greater and greater, the shorter the wave. This is true over the whole known range of radio wave lengths, so for what are known as short waves, the ground wave is of negligible importance.

The absorption of the reflected wave in the atmosphere, however, follows a very different law. Here the greatest absorption is found at a frequency of about 1,500 kilocycles, and becomes rapidly less as the frequency is either increased or decreased. From this it follows that, while on the short waves the reflected wave is the only one of importance, on the very long waves both the reflected and ground waves are active for many hundred miles from the transmitter. Beyond this—the distance from America to Europe, for instance—the ground wave, even at great wave lengths, becomes too weak to be of importance, and practically all of the signal is carried by the reflected wave in a series of reflections between the ionized layer and the earth. Up to 50 or 75 miles, however, for very long wave lengths, it is the ground wave which is of chief importance, since here

the reflected wave is weak in comparison. The strength of the reflected wave is very much greater at most frequencies at night than in the daytime, due to the fact that the absorption in the atmosphere is usually greatly increased in the daytime by the sun's rays. It is for this reason that, except on the longest wave lengths, reception is so much better at night than in the daytime.

The absorption of the ground wave, on the other hand, is believed to be nearly constant day and night, though, as has already been said, it changes with the wave length. It also differs very much with the character of the ground over which the wave travels. Over salt water it is probably constant for a given wave length all over the world.

A striking example of the high ground absorption in certain regions and its variation with wave length was observed in some experiments made several years ago by the U. S. Navy between Newport, R. I., and Brant Rock, Mass., a distance of 45 miles. Here it was found that with a frequency of 300 kilocycles the received signal was only 5 to 10 per cent of that which would have been received over salt water. At the same time, signals sent on a frequency of 75 kilocycles gave nearly the same intensity of reception as over water. At this short distance the reception was almost certainly due to the ground wave alone, as reflection could play only a negligible part in the phenomenon. A formula has been derived for the strength of signal over salt water in the daytime, and the observed and calculated values are nearly always in fair agreement. Over land, however, observed values differ greatly from those calculated from this formula, and differ very much among themselves on account of the differences in ground absorption in different regions. For this reason a station which may have practically the same range over land and water at night will have a daylight land range only a small fraction of its range over water.

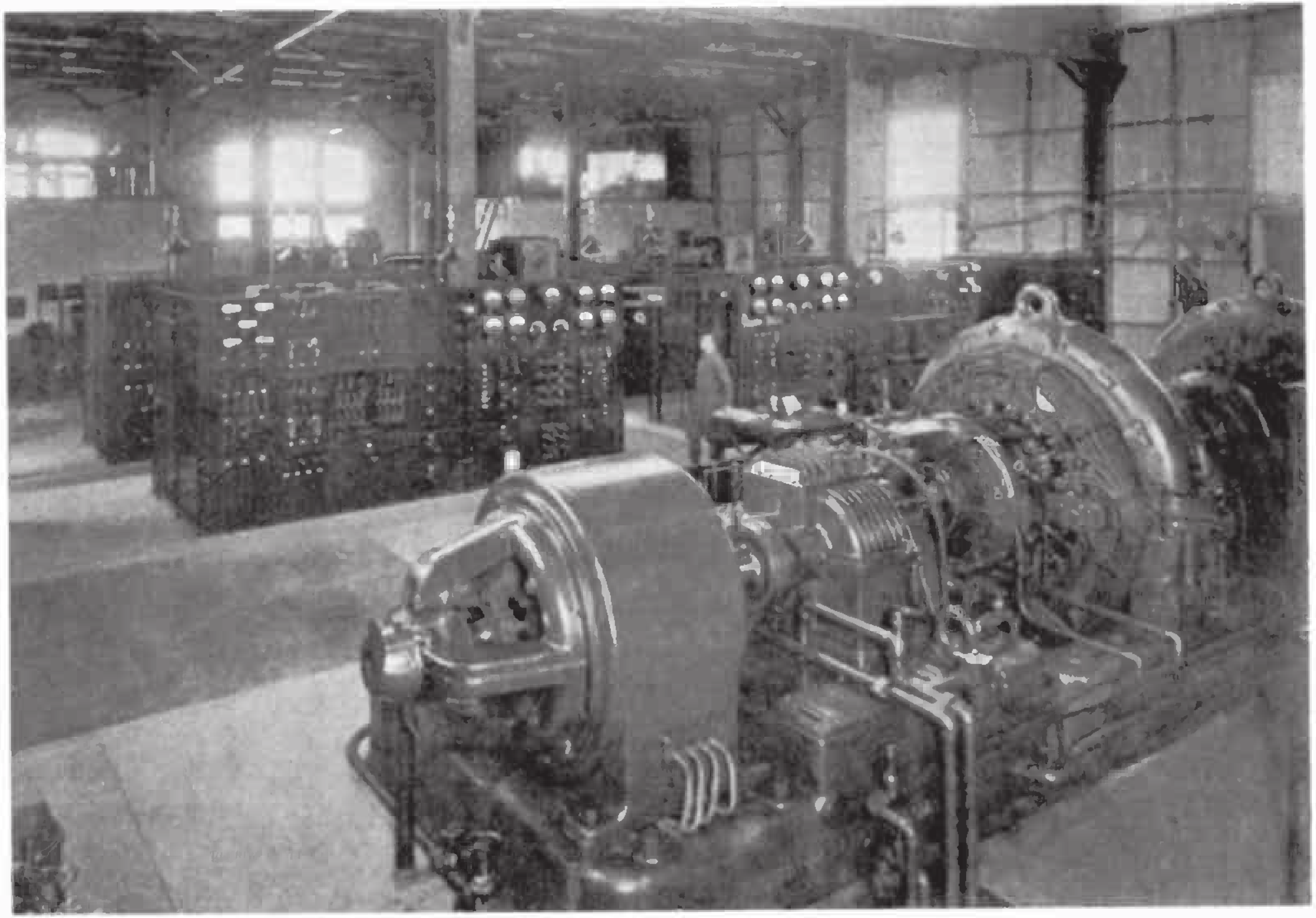
In general, we can say that the differences in behavior in waves of different lengths are probably due to the dif-

ferences in the amount of their absorption in the ground and in the air and in the way in which they are reflected or refracted in the upper atmosphere.

There are various reasons for the continued use of the long waves. It must, of course, be admitted that the short waves have many advantages, since their signals are radiated more efficiently from the antenna, are less absorbed in the upper atmosphere, and are less disturbed by static, and since their power plants and supporting masts are relatively small in cost compared with the huge alternators and enormous antenna-supporting towers required by long-wave stations for communicating over the same distances.

Notwithstanding these great drawbacks for the long waves, they have certain points of advantage, some of which are of the greatest weight. The most important quality of any method of communication is its reliability, and in this the long waves have the advantage. All wave lengths are subject to fading—that is, to changes in intensity of signal—and, generally speaking, fading decreases both in intensity and frequency as the wave length is lengthened, so that below 75 or 100 kilocycles it manifests itself merely in comparatively slight changes in intensity from hour to hour or day to day.

Fading is believed to be due to three causes. It is frequently produced, as has been mentioned, by interference between the ground wave and the reflected wave. At the greater distances, where the ground wave is negligible, two reflected waves traveling by different paths may produce the same result. A second cause may be the changes in the absorption of the reflected wave in the upper atmosphere. This may be likened to the changes in light from the sun as masses of cloud drift across the sky. Another type of fading particularly prevalent on the very short waves is probably due to the rotation of the plane of polarization of the electric oscillations in the wave, these at one moment being vertical so as to be received strongly on a



Transmitter Room of Rocky Point, Long Island, Transoceanic Radio Station of Radio Corporation of America, Showing the Alexanderson Alternator.

vertical antenna, and at the next horizontal so that they are not received at all. A suggested cure for this type of fading would be the use of vertical and horizontal antennas in combination.

Another cause of trouble in short wave transmission appears to be connected with the disturbances in the earth's magnetism, commonly known as magnetic storms. The severity and frequency of these interruptions of communication differ greatly in different portions of the earth, and are more severe when the transmission is at right angles to the magnetic lines of force than when parallel to them. For this reason, north and south communication is generally better than east and west, and in the case of east-west communication the signals are more constant near the equator than in the far north or south. Consequently, while most of the radio traffic of Europe and North America with South America is carried on by means of short waves, a considerable part of the communication between North America and Europe employs waves of less than 30 kilocycles.

T. L. Eckersley, of the Marconi Company, has recently furnished some information in regard to the frequency of this magnetic storm fading which is often so severe that the signals are entirely lost for several hours. He gives the following number of fade-outs between October, 1927, and October, 1928, in the communication between England and various points.

Melbourne, 7; Capetown, 4; Poona (India), 7; Buenos Aires, 4; Rio de Janeiro, 7; Java, 4; Montreal, 49; and New York, 32. It will be noticed how much more severe this form of fading is in the Montreal and New York communications than in the other cases. In comparison with these frequent difficulties in the case of the short waves, waves of 30 kilocycles or less are hardly affected at all by magnetic storms.

Another service, in which moderately long waves are apparently superior to the very short ones, is in direction-

finding by means of the radiobeacon or radiocompass. According to the experience of American observers, waves in the neighborhood of 300 kilocycles are found to be freer from the night errors, which produce the chief uncertainty in obtaining correct radio bearings, than waves which are very much longer or shorter. The superiority of this region of wave lengths for direction-finding is questioned by observers in England, where very extensive experiments by the British Radio Research Board indicate that there is very little difference in freedom from night errors in the whole range of frequencies from 15 to 1,000 kilocycles. This difference between the results obtained in England and in the United States may conceivably be due to different radio conditions in the two countries.

One more reason why long waves can probably never be replaced entirely by short waves is the amount of radio business in the world, which will eventually require every channel of communication from the shortest to the very longest wave length which can possibly be used.

The International Radiotelegraph Convention of 1927, adopted in Washington, determined the wave lengths which should be used for different purposes throughout the world. The band from 10 to 100 kilocycles is devoted to communication between fixed land stations. Most of the high-powered transoceanic services employ at present frequencies between 15 and 75 kilocycles, while 75 to 100 kilocycles are used mostly by fixed stations working over more moderate distances. The Bell Telephone System uses a low frequency of about 60 kilocycles for much of its transatlantic telephone service. This frequency is not low enough to give the most satisfactory signal strength at this distance, but was chosen to minimize interference with other services, since interference from telephone stations is particularly troublesome at the lower frequencies. The range from 100 to 150 kilocycles has been allotted to both fixed stations and ships.

Between 150 and 300 kilocycles all types of services

are found. Some European broadcasting stations are permitted to work in the neighborhood of 167 kilocycles where a long daylight range is desired. Broadcasting is also permitted between 194 and 286 kilocycles. The air services, too, operate in this band and between about 315 and 350 kilocycles. Radiobeacons use the band 285 to 315 kilocycles, and the radiocompass service operates between 360 and 390 kilocycles. The frequency of 500 kilocycles is the international calling and distress wave.